MANAV RACHNA INTERNATIONAL UNIVERSITY

Short Synopsis

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DESIGNING AND OPTIMIZATION OF MICROWAVE ANTENNA USED IN HYPERTHERMIA SYSTEM

DEPARTMENT OF ELECTRONICS AND COMMUNICATION

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ABSTRACT

Cancer is a disease caused by an uncontrolled division of abnormal cells in a part of the body. It is a major cause of death, and its incidence is increasing every day. Various methods and protocols are used which include chemotherapy, radiology, surgical removal of the tumor, etc. But these methods have many side effects that makes patient feel unbearable pain and inflict deep anxiety. Over the past decades, there is a struggle to discover new techniques to fight against cancer. Hyperthermia is an old therapy of treatment that gives new hope and which when combined with engineering techniques proves one of the best cancer treatment option. The critical element in hyperthermia system is an antenna whose performance determines the EM energy deposition into the tissue. Microwave ablation is a heating processes using microwave energy has a potential to be sensitive to change in the dielectric tissue parameters which results in damaging abnormal tissues. In order to produce heat in the focused area microwave signals are adjusted in time, frequency and strength. The commonly used frequencies in microwave imaging systems are 433MHz, 915MHz and 2.45GHz which are transmitted from the antennas enclosing the relevant body part. Enhancement of tumor temperature with EM energy is a complex task. The main objective of the research is to design, optimize, fabricate and compare different microwave antennas used in hyperthermia system. An antenna suffers much in terms of efficiency and matching, so there is a need for highly efficient antenna which provide more directivity and less return loss. Zealand Inc.'s IE3D is a full wave electromagnetic simulator based on method of moments is used to perform all simulations. It gives high efficiency, high accuracy and low cost electromagnetic simulation tool on PCs with window based graphic interface. The design evaluation and analysis of feed point location, E-field, efficiency, directivity, frequency of operation, 2D and 3D radiation pattern are presented in this research. After designing and fabrication the performance of microwave antenna is measured and analyzed for different applicators used in hyperthermia system.

KEYWORDS: Hyperthermia, Microwave Antenna, feed location, E-field, efficiency, Return loss, directivity, Radiation Pattern.

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1. Introduction

Cancer is one of the leading causes of death. Early cancer detection and adequate treatment are crucial in the control of disease. While chemotherapy and surgery are used for cancer treatment, some tumors cannot be treated by these therapies. Hyperthermia is a cancer treatment thermal process in which tumor loaded tissues are exposed to heat up to 42-46^{o}C. The biological response of hyperthermia is protein damage which involves both cellular and host related factors. It results in direct killing of raised temperature cancerous cells, increased metabolic activity, increased cell oxygenation, stimulation of immune system and an improvement of cells to drug intake. Microwave hyperthermia is one of the promising techniques that have been used in the treatment of patients suffering from cancer. Depending upon the size and location of tumor one or more microwave antennas are used in applicators for hyperthermia system. Based on the power absorption it raises the temperature of tumor and has a potential to create longer and effective thermal lesion at a greater depth. One of the main advantages is application time which is shorter for microwave frequencies. The federal communication commition (FCC) or International telecommunication union (ITU) permits several unrestricted frequency bands for industrial, scientific and medical uses in several regions including those most commonly used frequencies for microwave ablation are 433MHz, 915MHz and 2.45GHz. For the treatment of cancer patients having superficial tumors, waveguides and intracavity applicators have been used at frequency 2450MHz. The penetration depth of electromagnetic (EM) energy approaches the tumorous part with low irradiation in the vicinity of hyperthermia apparatus. Good impedance matching is achieved by microwave thermotherapy which can be effectively used in hyperthermia treatment of cancer.

To raise the temperature of tumor loaded tissue with EM energy is a difficult task. Determining factors include type and size of antenna, frequency of operation, feed location, directivity and efficiency. The design requirement of antenna for medical and in particular for hyperthermia applicators will be dealt in this research. The second part of the research will be concerned with optimization and fabrication of designs and will focus on the performance measurement and analysis of antennas used in applicators for hyperthermia system. The rest of the synopsis is organized as follows:

Section 2 contains the details of literature review; Section 3 gives the broad description of research topic. The objectives of this thesis are discussed in Section 4. Section 5 described the proposed methodology and in Section 6 the expected outcome of the research is discussed.

2. Literature Review

Research work in hyperthermia started in 20th century and the work carried out till date in this field are reviewed and discussed in this section. Storm et al. (1980) described the potential and progress of hyperthermia in cancer treatment. They described how high frequency current sources were first used to raise the temperature in hyperthermia treatment [36]. The concept of external applicator was given by Bahl et al. (1981) first time. They described how waveguide and micro strip antenna are used in hyperthermia system [4]. Dewhirst and Sim (1986) gave the estimation of therapeutic gain in clinical trials involving hyperthermia and radiotherapy. They explained the first clinical trial of hyperthermia on cancer patients [12]. Datta et al. (1990) explained the comparative results of thermo radiotherapy versus radiotherapy done for head and neck cancers [11].

Vrba et al. (1996) explained that the penetration depth of EM energy approaches the tumorous part with low irradiation in the vicinity of hyperthermia apparatus and good impedance matching is achieved by microwave thermotherapy which can be effectively used in local external hyperthermia treatment of cancer [40].The Ultrasound interstitial applicators for heating tumors near air and bone interfaces where use of noninvasive ultrasound methods becomes difficult was analyzed by Boguslaw et al. (1998)[5]. Jameset al. (2000) presented computer simulation and experimental measurement which investigate triangular and hexagonal arrays of sleeved slot interstitial microwave antenna to produce SAR distribution that offers a better scheme for hyperthermia treatment of brain tumors [16]. Marshall et al. (2000) proposed an inverse dynamic method that has a potential to become a useful tool for increasing treatment prescribability, increasing treatment efficiency and decreasing patient pain [22]. Arora et al. (2002) demonstrated a model predictive controller (MPC) in which thermal dose in hyperthermia cancer treatment is developed and can be elevated using simulations with one dimension and one point model of a tumor[3].The several unrestricted frequency bands for industrial, scientific and medical uses in several regions are described by Rosen et al. (2002) including those most

commonly used frequencies for microwave ablation [33]. Ardith et al. (2004) described the effects of the combined process of giving a drug with the delivery of heat as it includes increased capturing of the drug by the cell, increased killing of tumor cells [1]. Juang et al. (2004) described a conformal microwave array (CMA) applicator that uses a temperature controlled water bolus to treat breast carcinoma [20]. Jessi et al. (2006) presented an automatic control system for accurate temperature control of hyperthermia treatments with multiple array applicators [18]. Riadh et al. (2006) described the biological response of hyperthermia in which there is aprotein damage which involves both cellular and host related factors. Microwave ablation has a potential to be sensitive to change in the dielectric tissue parameters which results in damaging abnormal tissues [32].The numerical FEM model of a magnetic fluid hyperthermia (MFH) treatment on a hepatocellular carcinoma (HCC) metastasis was analysed by Candeo and Dugherio (2009).They explained that the reduction of treatment times is an important issue to be considered during thermal therapy [9].Martin (2009) presented the model of microwave hyperthermia treatment using COMSOL Multiphysics 4.1. The model of agar jelly with properties similar to the biological tissue was developed [23]. Max and Curto (2009) described that hyperthermia results in direct killing of raised temperature cancerous cells, increased metabolic activity, increased cell oxygenation, stimulation of immune system and an improvement of cells to drug intake [25].

The narrowband wide beam Micro strip patch antenna which is mostly used at microwave frequencies is described by Qureshi et al.(2011).They described that the size of the antenna is directly tied to the wavelength at resonant frequency .They also explained how thicker substrate will increase the radiation power, reduce conductor loss and improve bandwidth [31].Omer et al. (2012) presented the adequateness of a rectangular spiral shaped patch antenna and a Vivaldi antenna having narrow beam width to use for antenna arrangements in microwave hyperthermia applications. Its small lateral size is promising to use it in multi antenna configuration system for microwave hyperthermia application for cancer treatment [27].How the position of the feeding changes the results is explained by Patil (2012). He explained the Micro strip line feeding in which a conducting strip is connected directly to the edge of micro strip patch [29]. Suganthi et al. (2012) presented a new miniaturized fractal antenna as a combination of Murkowski and Koch curves. The structure of the proposed antenna is the result of the modifications made with the basic fractal square and triangular curves [37]. Kumar et al. (2012)presented the 3D model

waveguide applicator for hyperthermia treatment. Finite element full wave modeling has been performed to predict at high degree of performance of 3D model of applicator [28].

New methods for treatment of cancer that have been implemented have been successful, but the results are still limited. Many researchers are still doing work on different shapes of antenna designs employed for medical use and in particular for hyperthermia applicators. Various optimization techniques are being explored to effectively improve the performance characteristics of antenna.

3. Description of broad area

Hyperthermia is defined as the delivery of controlled heat to the diseased tissues without damaging surrounding healthy tissues. The microwave antenna used in the hyperthermia system require the calculation of interaction of E-field with a tissue, Specific absorption rate and the temperature rise in the exposed human tissue which are obtained by using equations given below:

Antenna human tissue interaction: Because the body has low permeability the absorbing effect of EM energy is principally associated with tissue permittivity losses[14][15]. The interaction of E-field with a tissue is described by equation (1)

$$\epsilon = \epsilon_o(\epsilon_r - j\epsilon'') \quad (1)$$

Where ϵ_o is permittivity of free space

ϵ_r is dielectric constant

ϵ'' is indication of energy transferred from incident E field to the tissue

Specific absorption rate (SAR): The specific absorption rate gives the rate of energy absorption in biological tissue which is given by equation (2)

$$\text{SAR} = \frac{P}{\rho} = \frac{\sigma|E^2|}{\rho} \quad (2)$$

Where P is power absorbed in the tissue (W)

σ is electrical conductivity (S / m)

$|E|$ is rms magnitude of electric field strength (V / m)

Temperature: The temperature rise in the exposed human tissue is given by Penne's bio heat equation(3)

$$\rho C \frac{\delta T}{\delta t} = \Delta.(K \Delta T) - \rho_{blood}\ w\ C_{blood}\ (T - T_{core}) + Q_m + SAR_\rho \quad (3)$$

Where **ρ** is material density (kg /m^3)

C is specific heat capacity (J /kg/^{o} C)

T is variable quantity of temperature (^{o} C) at a time (s)

K is thermal conductivity (W /m/^{o} C)

ρ_{blood} is blood density(kg /m^3)

w is perfusion of blood (ml/100g/min)

C_{blood} is blood heat capacity (j/kg/^{o} C)

T_{core} is blood temperature (^{o} C)

Q_m is heat generated by metabolism (W /m^3)

Depending upon the absorption of power, microwave antenna used in applicators raise the temperature of tumor. It has a potential to create longer and effective heating at a greater depth. It offers the advantage of application time which is shorter for microwave frequencies. The three commonly used frequencies in microwave imaging system are 433MHz, 915MHz and 2450 MHz. The waveguide and intracavity applicators used for the treatment of cancer patients having superficial tumors use frequency of 2450 MHz. Micro strip patch antenna is a narrow band wide beam antenna which is mostly used at microwave frequencies. The antenna consists of radiating patch on one side of dielectric substrate which has ground plane on the other side [13][17]. The commonly used substrate is FR_4, Honeycomb, Duroid and Quartz. Thicker substrate will increase the radiation power, reduce conductor loss and improve bandwidth. Fig.1 shows the basic diagram of micro strip patch antenna.

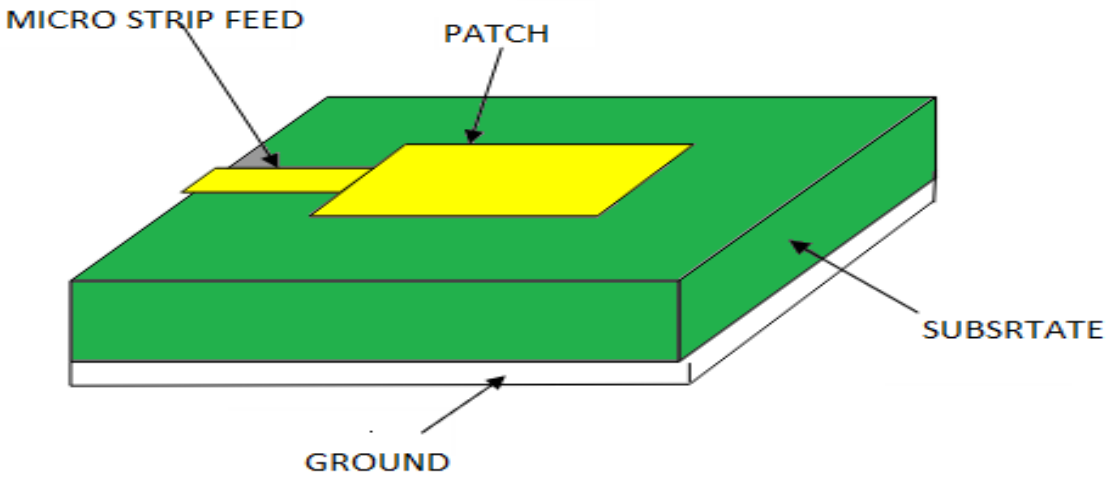


Fig.1 Micro strip patch antenna

The patch acts approximately as a resonance cavity in which only certain modes are allowed to exist at different resonant frequencies. If the antenna is allowed to excite at resonance frequency a strong field is set up inside a cavity and a strong current on the surface of the patch [30]. This produces significant radiation. The micro strip antenna can be designed in various shapes. The commonly used shapes of antenna are square, dipole, spherical, circular, rectangular, elliptical and triangular as shown in Fig.2

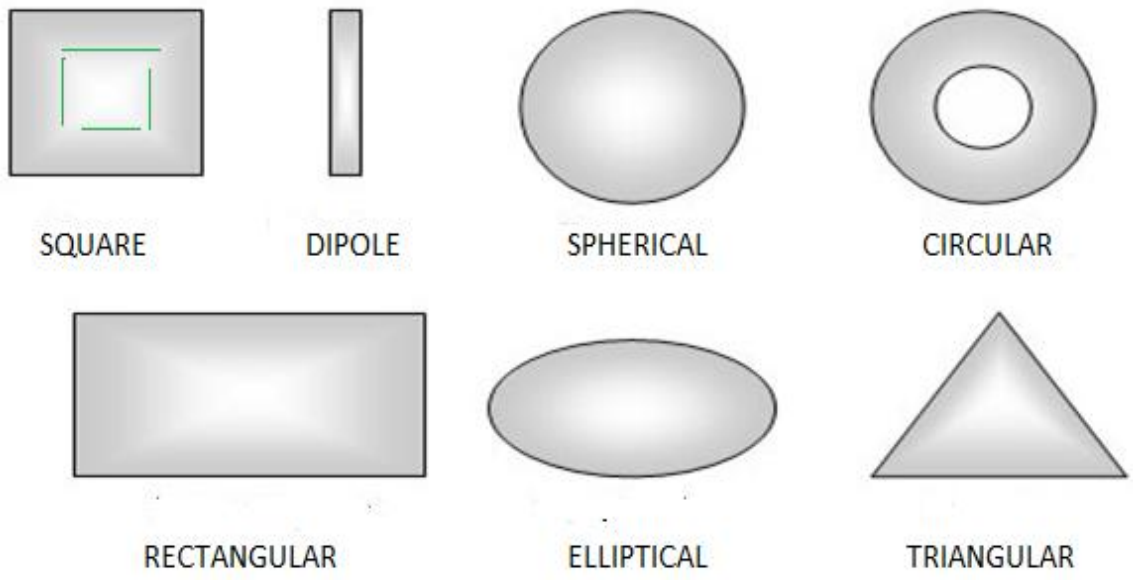


Fig.2 Different shapes of micro strip antenna

The most commonly used shapes are rectangular and circular. The flowchart describing the process of designing microwave micro strip patch antenna is shown in Fig.3. First the required parameters of the antenna are calculated for different design equations. For designing and simulation of antenna design various commercial software packages are available like CST microwave studio, HFSS, IE3D etc.IE3D software uses a method of moment (MOM) numerical technique which has been effectively applied to electromagnetic problems related to human body.IE3D has inbuilt optimizer which can be used to improve the performance parameters.

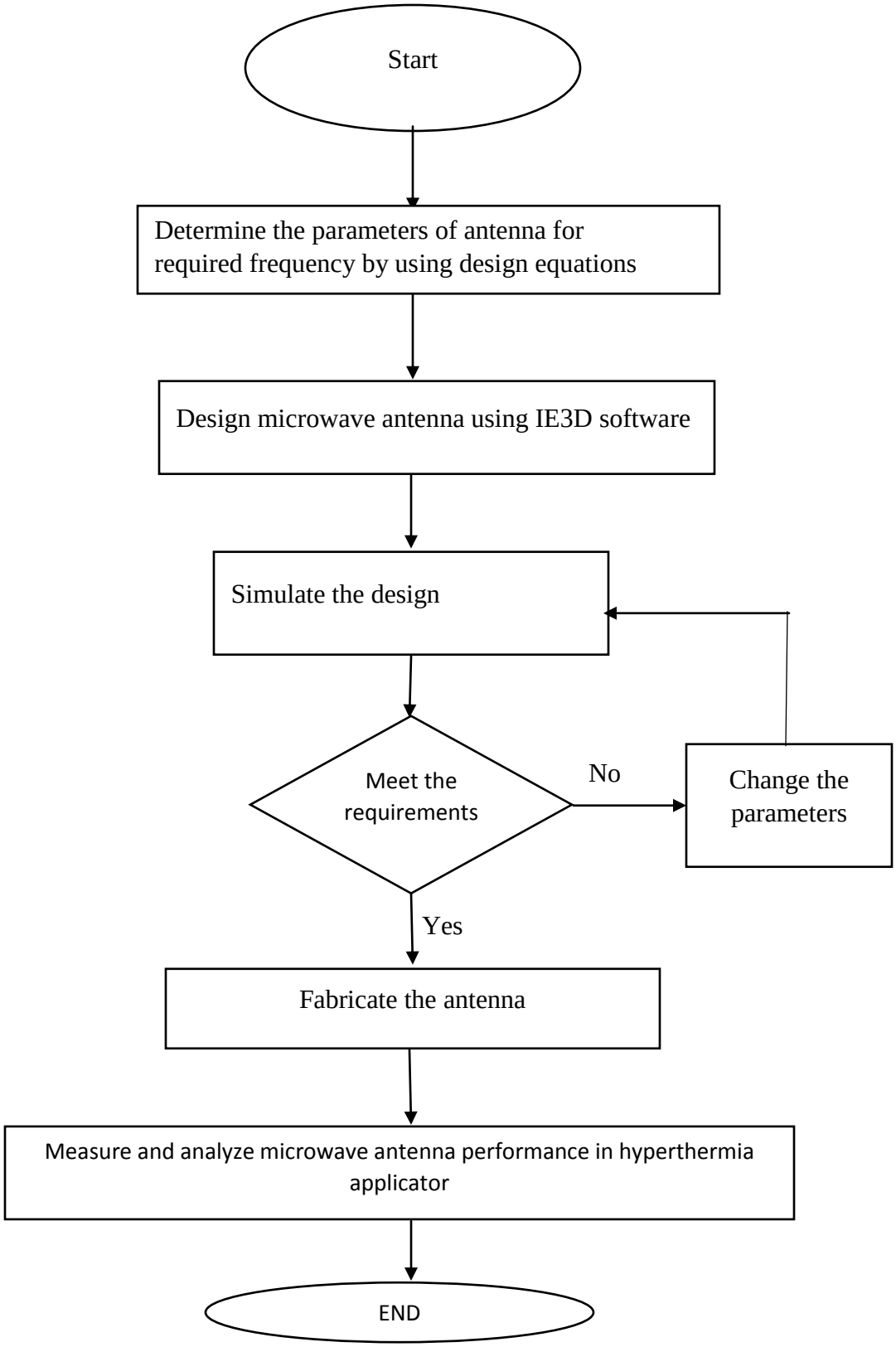


Fig.3 Flowchart design process of microwave micro strip patch antenna in IE3D software

The equations for rectangular patch micro strip antenna design[6] are:

Calculation of Width: The first step in antenna design is to calculate the width of micro strip patch antenna which is given by equation (4)

$$W = \frac{C}{2f_o\sqrt{\frac{\epsilon_r+1}{2}}} \quad (4)$$

Calculation of Effective Dielectric Constant: To calculate the actual length of micro strip antenna first calculate the effective dielectric constant which is given by equation (5)

$$\epsilon_r = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left(\frac{1}{\sqrt{1+12\frac{h}{W}}}\right) \quad (5)$$

Calculation of Effective Length (L_{eff}): The effective length of the microwave antenna can be calculated by using equation (6)

$$L_{eff} = \frac{C}{2f_0\sqrt{\epsilon_{eff}}} \quad (6)$$

Calculation of the length extension (ΔL): To find the actual length it is required to find the length extension by using equation (7)

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{eff}+0.3)}{(\epsilon_{eff}-0.258)}\frac{\left(\frac{W}{h}+0.268\right)}{\left(\frac{W}{h}+0.8\right)} \quad (7)$$

Calculation of actual length (L): The actual length of the microwave patch antenna is calculated by using equation (8)

$$L = L_{eff} - 2\Delta L \quad (8)$$

For practical considerations, there is a need for finite ground plane.It can be calculated if size of ground plane is six times greater than thickness of substrate and given by equations (9) and (10)

$$L_G = L + 6h \quad (9)$$

$$W_G = W + 6h \quad (10)$$

Design equations for circular micro strip patch antenna [6]:

The circular patch antenna on rectangular ground plane is shown in fig.4.The radius (a) of circular patch is calculated by using equation 11.

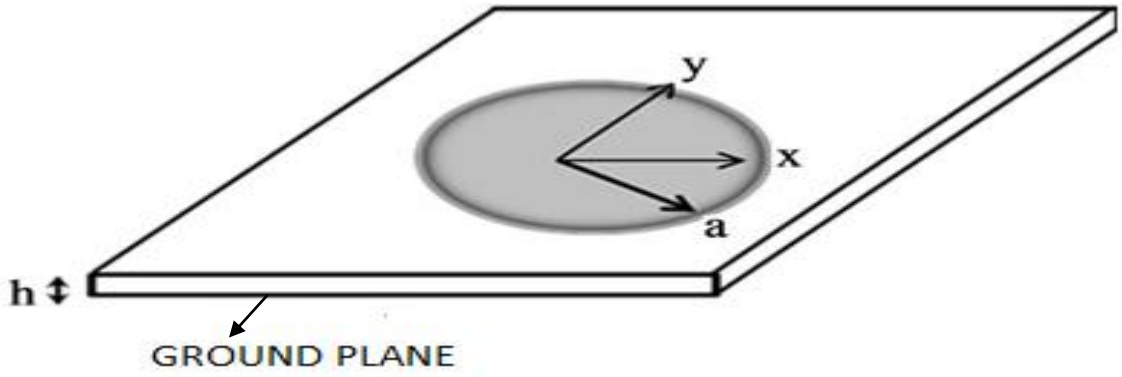


Fig.4 Circular patch antenna

Radius of circular patch is

$$a = \frac{F}{\sqrt{1+\frac{2h}{\pi\epsilon f\left[ln\left(\frac{\pi F}{2h}\right)+1.7726\right]}}} \quad (11)$$

$$\text{Where } F = \frac{8.791 * 10^{9}}{f_{r\sqrt{\epsilon}}}$$

By using the design equations, microwave antenna of desired shape can be designed and simulated on IE3D. If the desired requirements are met then antenna will be fabricated otherwise there is a need to change some parameters. After fabrication the antenna performance need to be analyzed for hyperthermia applicator system. The various parameters which will be analyzed for microwave antennas are return loss, directivity, VSWR, antenna efficiency, gain, directivity, and impedance.

4. Objectives of study

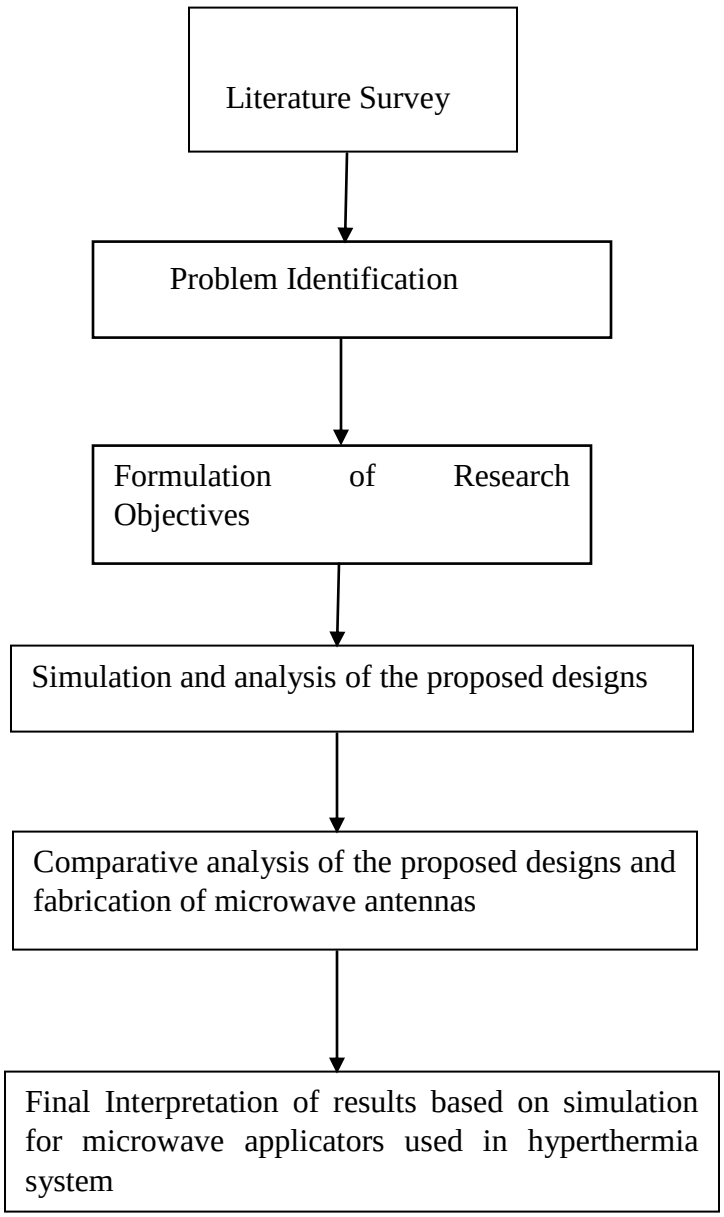
Hyperthermia is a type of cancer treatment in which body tissue is exposed to high temperature using external and internal heating devices. The difficulty in limiting heat close to the tumor region without damaging the healthy tissue is a technical challenge in hyperthermia. Energy absorption in cancerous tissues provides heat required for temperature increase. Keeping in mind these challenges the objectives of the research work are

1. To analyze EM spectrum for microwave antenna.

2. To design microwave antennas which can be used for hyperthermia for a particular frequency.
3. To study the electrical and thermal properties of human tissues.
4. To compare and optimize microwave antenna designs on IE3D simulator.
5. To fabricate and measure the performance for microwave applicators used in hyperthermia system.

5. Methodology to be adopted

The proposed methodology is given below:


Literature Survey
Problem Identification
Formulation of Research Objectives
Simulation and analysis of the proposed designs
Comparative analysis of the proposed designs and fabrication of microwave antennas
Final Interpretation of results based on simulation for microwave applicators used in hyperthermia system

6. Proposed outcome of the research

The aim of the hyperthermia treatment is to raise the temperature of tumor loaded tissues to 40-44 ^{o}C. Based on electrical and thermal properties of human tissues various microwave antennas will be designed and compared on IE3D Simulator so that effective results can be used in applicators of hyperthermia system. By utilizing the capabilities of optimization tools the proposed designs will give more directivity, high efficiency and low return loss. The optimized designs will then be fabricated and tested to measure and analyze the microwave antenna performance in hyperthermia applicators.

7. Proposed Time Frame (Gantt Chart)

Research Plan

	Sem1 (June'13)	Sem2 (Dec'13)	Sem3 (June' 14)	Sem4 (Dec'14)	Sem5 (June'15)	Sem6 (Dec'15)	Sem7 (June'16)	Sem8 (Dec'16)
Course work								
Literature Review								
International paper presentation and publication								
Data collection								
Data study								
Interpretation of data								
Thesis submission								

8. REFERENCES

[1] Ardith W. El-Kareh and Timothy W. Secomb. (2004)' A Theoretical Model for Intraperitoneal Delivery of Cisplatin and the Effect of Hyperthermia on Drug Penetration Distance', *Neoplasia*,Vol. 6, No. 2, pp. 117 – 127

[2] Ashwini K., Arya, Kartikeyan M.V., Patnaik A. (2010) 'Defected Ground Structure in the perspective of Micro strip antenna', Vol.64, Issue5-6, pp.79-84.

[3] Arora D., Mikhail S. and Robert B. R. (2002)'Model Predictive Control of Ultrasound Hyperthermia Treatments of Cancer', *Proceedings of the American Control Conference Anchorage*, pp.1627-1632

[4] Bahl I.J., Stuchly S.S., Lagendijk J.W. and Stuchly M.A. (1981) 'Micro strip loop radiators for local hyperthermia', *Proc. IEEE MTT International Microwave Symposium*, pp. 465-467.

[5] Boguslaw J. J. and Doru K. (1998) 'Ultrasonic Heating with Waveguide Interstitial Applicator Array', *IEEE Transactions of Instrumentation and Measurement*, vol.47, No.3, pp. 703-707.

[6] Balanis C. A. 'Antenna Theory, Analysis and Design' 3rd ed. Hoboken, NJ: Wiley, 2005.

[7] Bird, Trevor S. (2009) 'Definition and Misuse of Return Loss'. *IEEE Antennas and Propagation Society.* Vol. 51, Issue 2, pp. 166-167.

[8] Chou C-K. (2005)'Evaluation of microwave hyperthermia applicators',*Bio electromagnetics*,vol.13: pp.581–97.

[9] Candeo A. and Dugherio F.(2009) 'Numerical FEM model for the planning of magnetic induction hyperthermia treatment with nanoparticles', *IEEE Transactions on magnetics*, vol.45, No.3.

[10] Cheung A.Y. (1987) 'Microwave hyperthermia for cancer therapy'. *IEE Proc. 1987*. 134: pp. 493–522.

[11] Datta N.R., Bose A.K., KapoorH. K., and Gupta S. (1990) 'Head and neck cancers: results of thermo radiotherapy versus radiotherapy',*International Journal of Hyperthermia*, vol. 6, no. **3,** pp. 479-486.

[12] DewhirstM. W. and SimD. A. (1986) 'Estimation of therapeutic gain in clinical Trials involving hyperthermia and radiotherapy',*International Journal of Hyperthermia*, vol. 2, no. 2, pp. 165-178.

[13] Dua R.L., Singh H. and Gambhir N. (2012)'2.45 GHz Micro strip Patch Antenna with Defected Ground Structure forBluetooth', Vol-1, Issue-6, pp 262-265.

[14] Fessenden P. and Hand J.W.(1995)'Hyperthermia therapy physics',*In: Smith AR, Editor. Medical radiology: radiation therapy physics. Berlin: Springer-Verlag*. pp. 315–63.

[15] Gelvich E.A. and Mazokhin V. N (2001) 'Technical aspects of electromagnetic hyperthermia in Medicine' *Crit Rev Biomed Eng.* 29: pp.77–97.

[16] James C. L., Chin L. H. and Wang Y.J.(2000) 'Computer Simulation and Experimental Studies of SAR Distributions of interstitial arrays of sleeved slot microwave antennas for hyperthermia treatment of brain tumors',*IEEE Transactions on microwave theory and techniques*, Vol.48, no. 11.

[17] James J. R. and Hall P. S(1985). 'Handbook of micro strip antennas'. *Peter Peregrinus*, London, UK.

[18] Jessi E. J. and Neuman D (2006). 'Automatic Temperature Controller for Multi 'element Array Hyperthermia Systems',*IEEE Transactions on Biomedical Engineering*, vol.53, no.6, pp.1006-1015.

[19] Jouvie F., Bolomey J.C. and Gaboriaud G. (1986)' Discussion of Capabilities of Microwave Phased arrays for Hyperthermia Treatment of Neck Tumors', *IEEE Transactions on Microwave Theory and Techniques*, vol. 34, pp. 495-501.

[20] JuangT., NeumanD., SchlorffJ. and Stauffer P. R.(2004)' Construction of a Conformal Water Bolus Vest Applicator for Hyperthermia Treatment of Superficial Skin Cancer', *Proceedings of the 26th Annual International Conference of the IEEE EMBS San Francisco, CA, USA*,pp-686-698.

[21] KimJ. and Rahmat SamiY.(2003)' an implantable antenna in the spherical human head: SAR and communication link performance',*presented at the IEEE Topical Wireless Communication Technology Conf.*, DOI: 10.1109/WCT.2003.1321490

[22] Marshall M., Robert B. R. and Devasia S. (2000)'Exact Temperature Tracking for Hyperthermia: A model Based Approach',*IEEE Transaction on control systems Technology*, vol.8, no.6, pp.979-992.

[23] Martin B. (2009) 'Design of Microwave Hyperthermia treatment,' Volume ISBN: 0-87014-355-7.2009

[24] Magin R.L and Peterson A.F. (1989) 'Noninvasive microwave phased arrays for local hyperthermia: a review', *Int J Hyperthermia*. Vol 5. pp. 429–50.

[25] Max J. A. and Curto S. (2009)'Compact Patch Antenna for Electromagnetic Interaction with Human Tissue at 434 MHz',*IEEE Transaction on Antennas and propagation*. Vol. 57, No. 9, September 2009.

[26] Moroz P., Jones S.K., and Gray B.N.(2002)'magnetically mediated hyperthermia: current status and future directions',*Int J Hyperthermia.* 2002; Vol.18, pp.267–84.

[27] Omer I., Korkmaz E., and Türetken B. (2012) 'Antenna Arrangement Considerations for Microwave Hyperthermia Applications'.*IEEE Transaction on Antennas and propagation*, 978-1-4244-6051.

[28]Kumar P., Kalra S. and Marwaha A. (2012) 'Design optimization of waveguide applicator form Microwave Hyperthermia Cancer treatment', *http://www.comsol.co.in/offers/coonference2012 papers/ presentation/area/electromagnetics/id*/14077.

[29] Patil V. P. (2012)' Enhancement of bandwidth of rectangular patch antenna using two square slots techniques'*International Journal of Engineering Sciences & Emerging Technologies,*. ISSN: 2231 – 6604. Volume 3, Issue 2, pp: 1-12.

[30] PozarD. M. and Schaubert D. H. (1995)' Micro strip Antennas, the Analysis and Design of Micro strip Antennas and Arrays'. IEEE Press, New York, USA

[31] Qureshi A. and Afzal M.U. (2011)' Performance analysis of FR-4 substrate for high frequency micro strip antennas'. IEEE Microwave Conference Proceedings (CJMW), China-Japan Joint.

[32] Riadh W. Y. H, Bansal R. (2006) 'Thermal Therapy, Part 2: Hyperthermia Techniques. Critical Reviews TM in Biomedical Engineering' Vol. 34(6), pp: 491–542.

[33] Rosen A., Stuchly M.A. and Van Vorst A. (2002)' Applications of RF/microwaves in medicine'*IEEE Trans. Microwave. Theory Tech.,*Vol. 50, pp. 963–974.

[34] Saiyed Z.M., Telang S.D., and Ramchand C. N. (2003)' Application of magnetic techniques in the Field of drug discovery and biomedicine'. *Biomagn Res Techno*. , Vol.1, pp. 42–50.

[35] SneedP. K. and PhillipsT. L. (1991) 'Combining hyperthermia and radiation: How beneficial?'*Oncology,* vol. 5, pp. 99-108.

[36] StormF. K., ElliottR., HarrisonW. H. and MortonD. L. (1980)'Hyperthermia in cancer treatment: Potential and progress'*Practice Oncology for the Primary Care Physician,* vol. 1, pp. 42-52.

[37] Suganthi S., KumarD. and RaghavanS. (2012)'Design and Simulation of Miniaturized Multiband Fractal Antennas for Microwave Applications'*International Journal of Information and Electronics Engineering,* Vol. 2, No. 5.

[38] StaufferP. R., LeonciniM. and ManfriniV. (1995) 'Dual concentric conductor radiator for microwave hyperthermia with improved field uniformity to periphery of aperture',*IEICE Trans. on Communication,* Vol. E78-B, pp. 826-35.

[39] Trefna H. D., Vrba.J. and PerssonM. (2010)' Time-reversal focusing in microwave hyperthermia for deep-seated tumors', Physics in Medicine and Biology, Vol. 55, No. 8, pp.2167–2185.

[40] Vrba J., FranconiJ., LapesC.M. (1996) 'Theoretical Limits for the Penetration Depth of Intracavity Applicator. Int. J. of Hyperthermia', No.6.pp.737–742.

[41] Wang. G., GongY., and WangH. J. (2009)' Schemes of microwave hyperthermia by using flat left-handed material lenses'. *Microwave and Optical Technology Letters*, Vol. 51, No. 7, pp.1738–1743.

[42] XiaW., SaitoK., TakahashiM., and ItoK.' Performances of an implanted cavity slot antenna embedded in the human arm',*IEEE Trans.Antennas Propag.* vol. 57, pp. 894–899.

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